Virginia Space Grant Consortium

Small Sat Virginia Initiative

For JCOTS Nanosatellite Advisory Committee

Mary Sandy, Director

June 17, 2015

NSGA
National Space Grant Alliance

America's Space Grant Program

Aerospace-Related Education, Workforce Development and Research

52 Consortia:

Every state + D.C. and Puerto Rico

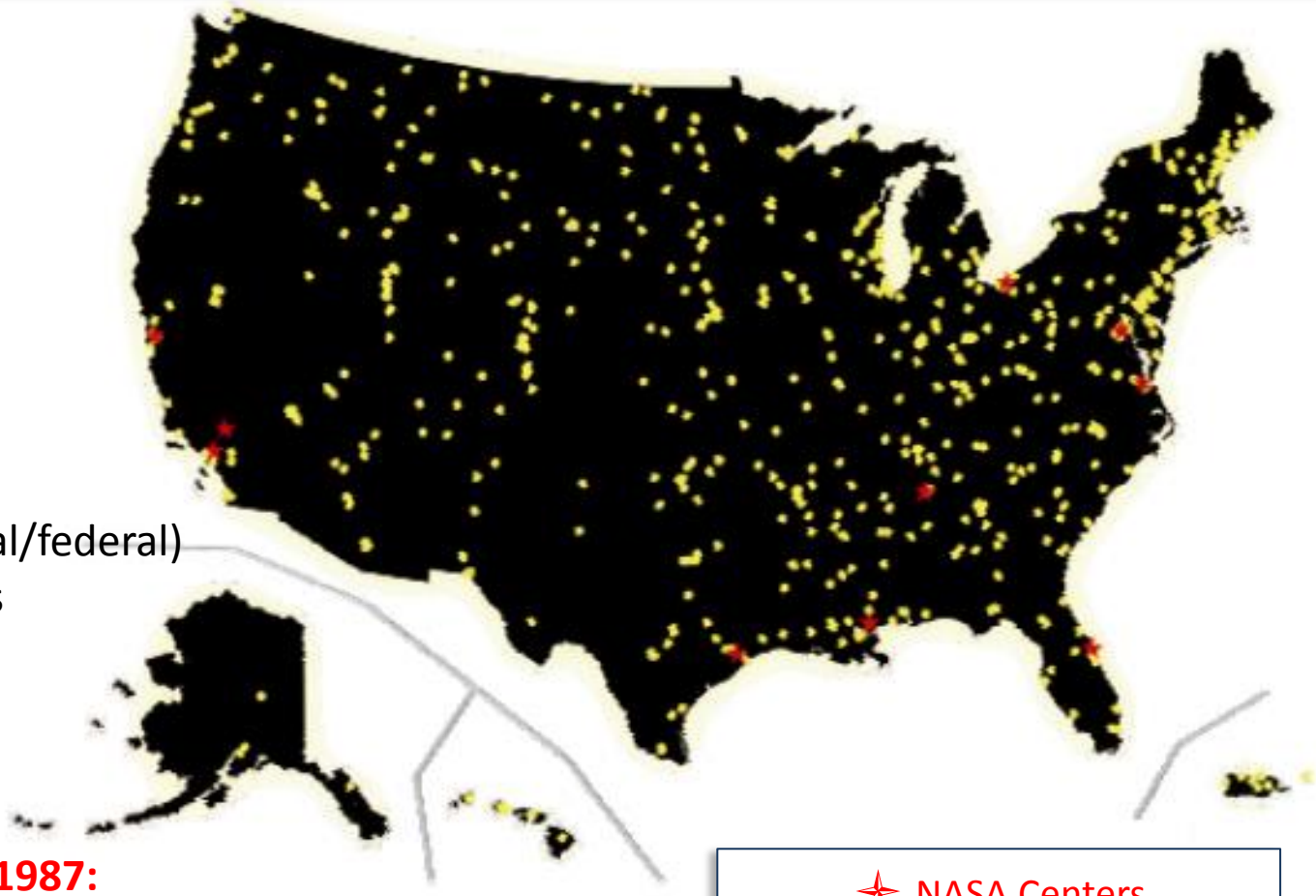
987+ Affiliates:

652 higher education
87 industry
83 governmental (state/local/federal)
76 museum/science centers
89 other local partners

Public/Private Partnerships

Established by Congress in 1987:
Public Law 100 - 147

Virginia Space Grant began in 1989

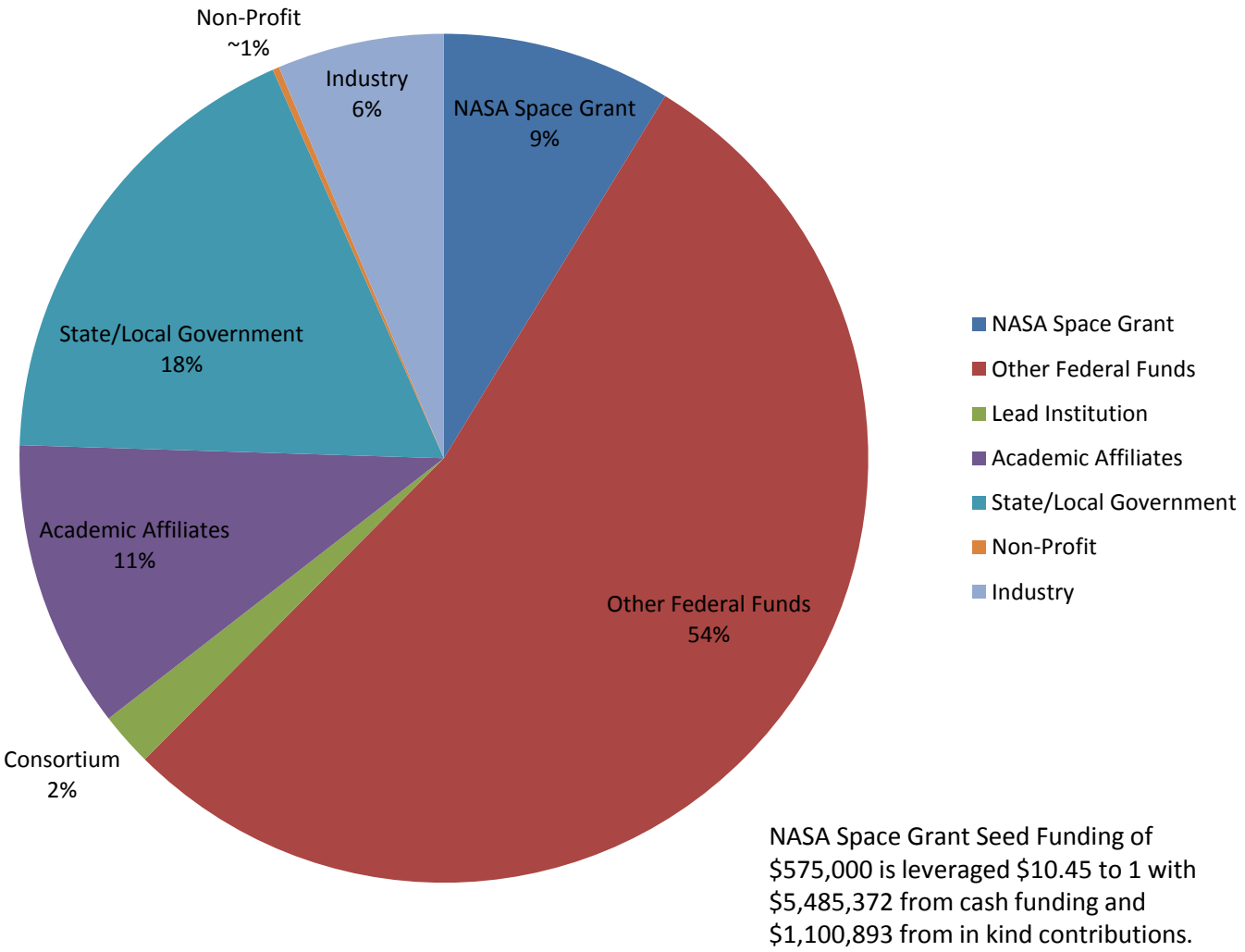


VSGC Member Institutions

College of William and Mary
Hampton University
Old Dominion University
University of Virginia
Virginia Polytechnic Institute and State University
NASA Langley Research Center
NASA Goddard Space Flight Center's Wallops Flight Facility
State Council of Higher Education for Virginia
Virginia Community College System
Virginia Department of Education
MathScience Innovation Center
Science Museum of Virginia
Virginia Air and Space Center
Center for Innovative Technology

VSGC has worked with more than 500 program partners

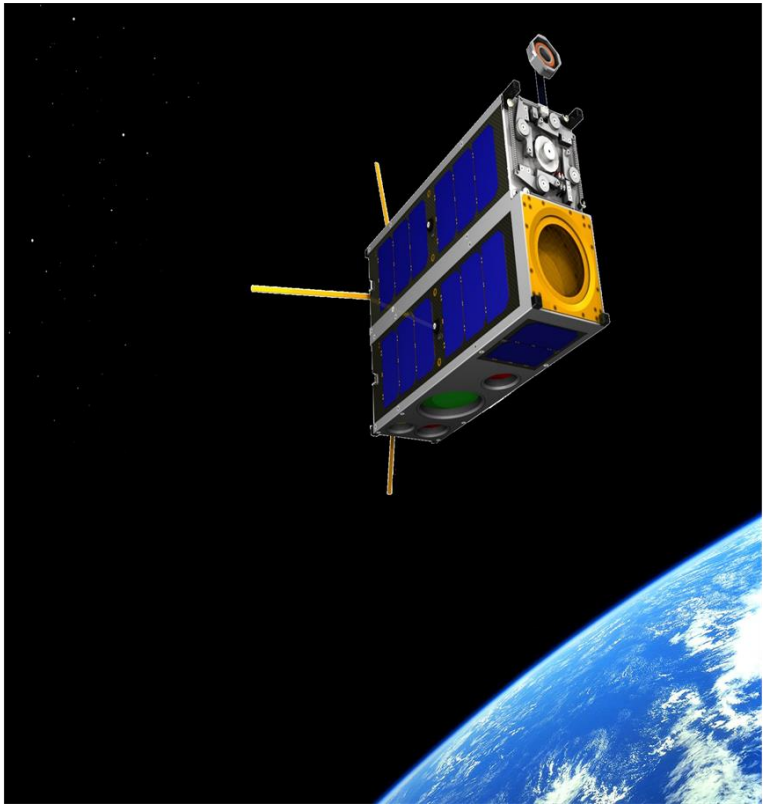
FY 2014 Funding for Virginia Space Grant Consortium



NASA Space Grant Seed Funding of $575,000 is leveraged $10.45 to 1 with $5,485,372 from cash funding and $1,100,893 from in kind contributions.

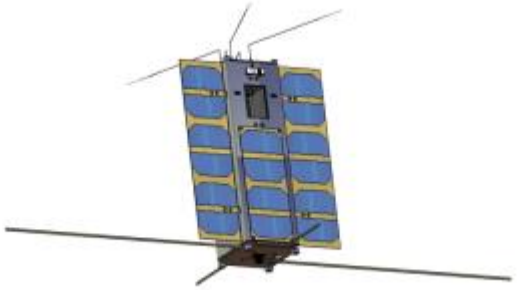
Student Flight Programs

- Cubesats
- Sounding rocket missions
- Microgravity experiments
- Space Station experiments
- Research balloon payloads
- Airborne experiments
- Design projects



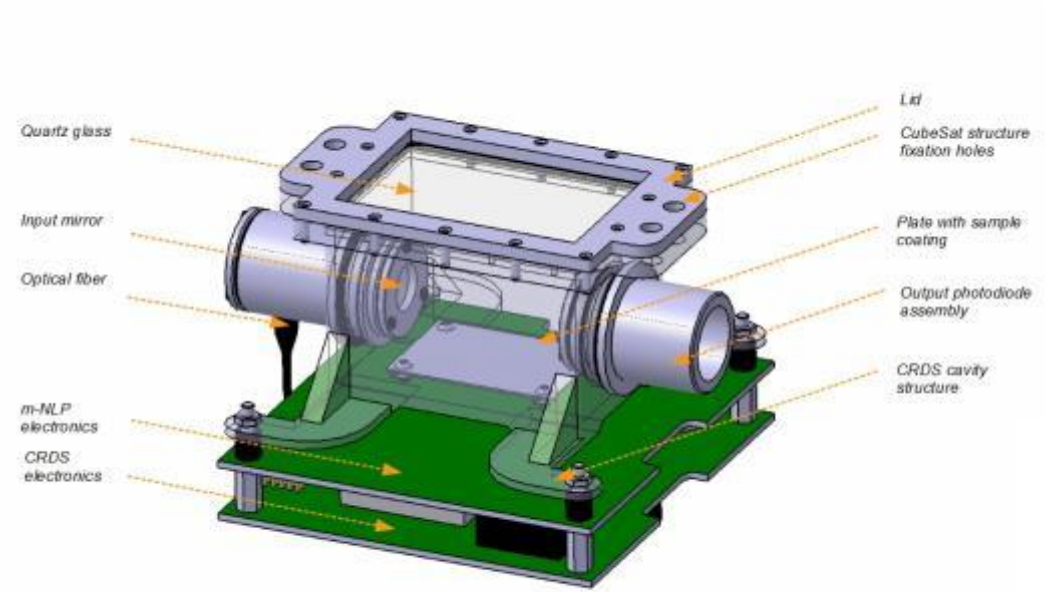
OGMS-SA Satellite Project

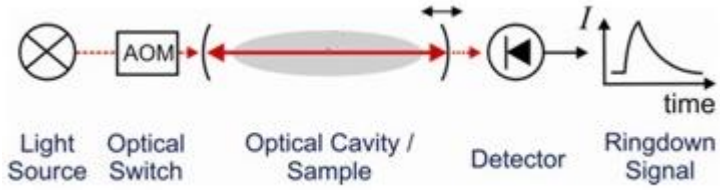
- **Small Satellite Project (3U) with the following French institutions: Université Paris-Est Créteil (UPEC); Observatoire de Paris-Meudon (OBSPM); Centre National de la Recherche Scienctifique – Institut National des Sciences de L'Univers (CRNS-INSU); Center National d' Études Spatiales (CNES), Paris.**
- **VSGC has administrative lead for US collaboration; Virginia Tech has technical lead. ODU is also participating.**
- **Cubesat is part of QB-50 program and demonstrates a new Cavity Ring Down spectrometer that studies material degradation from UV exposure and gas trace analysis of the low earth orbit environment. Space plasma characterizations will be made via a Langmuir probe.**
- **ODU and VT to provide ground tracking.**
- **French students to Virginia in summer 2015.**
- **Have U.S. Department of State Technical Assistance Agreement.**
- **Launch as early January 2016 on a Ukrainian rocket from a commercial spaceport in Brazil.**

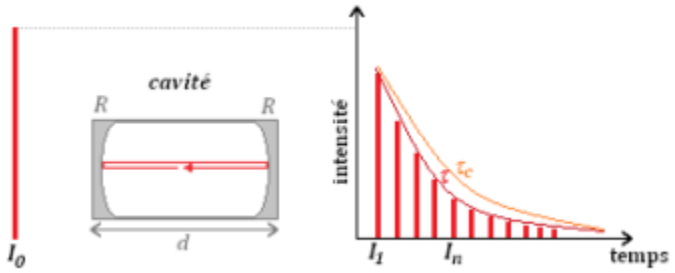


OGMS-SA

The mission : to demonstrate the reliability of a miniaturized CRDS (*Cavity Ring Down Spectrometer*) in space







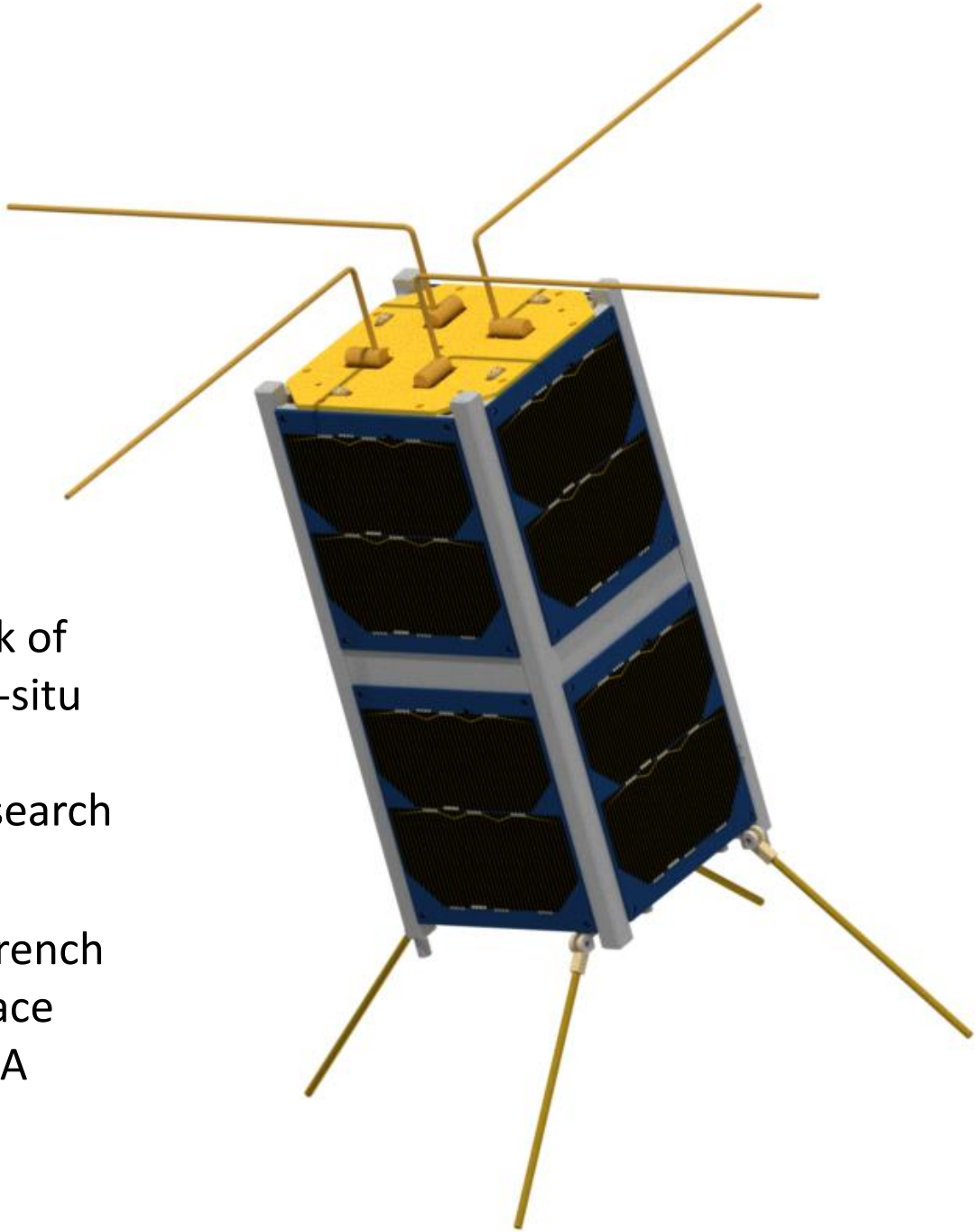
Secondary Payload :

Multi-Needle Langmuir Probes

QB50

QB50, an international network of 50 CubeSats for multi-point, in-situ measurements in the lower thermosphere and re-entry research

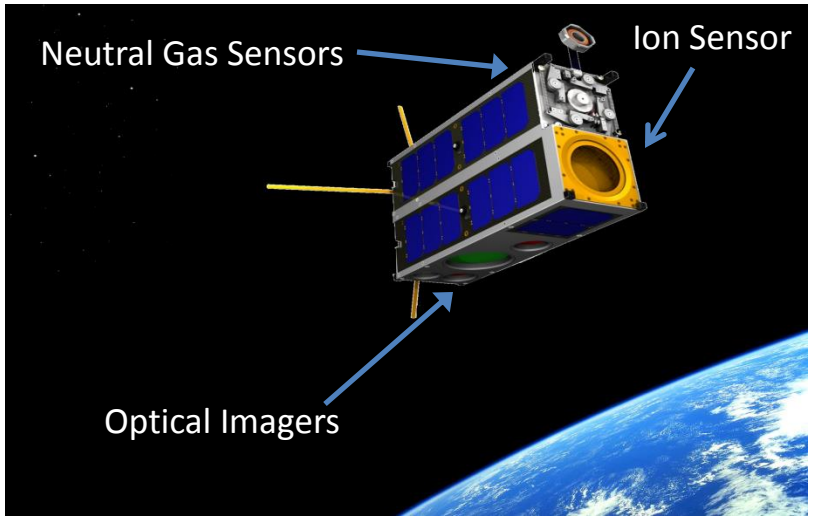
VSGC is working with several French universities and the French Space Agency (CNES) for the OGMS-SA Cube Sat that is part of QB-50.



Space @ Virginia Tech
Center for Space Science and Engineering Research

LAICE – Mission Details

Lower Atmosphere/Ionosphere Coupling Experiment



6U Cubesat w/ 3 instruments on NASA Manifest

Orbit	300-450 km circular, 45-100°
Data Rate	100 Mb/day
ADACS	5° accuracy, 1° knowledge
Mass	~ 8 kg
Power	S/C: 0.98 W, Payload: 3.45 W

Mission Overview:

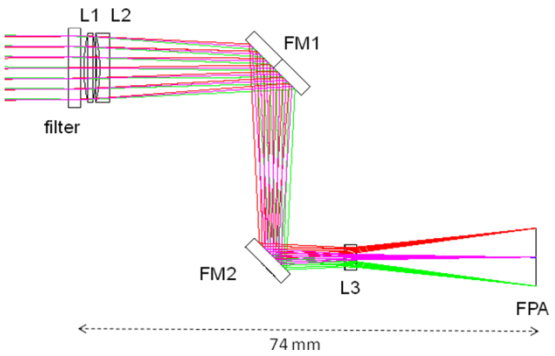
1. Mission will measure effects of terrestrial weather systems on the LEO space environment.
2. Data downlink through NASA Wallops, command uplink through VT and Illinois.
3. Partners: U of Illinois, The Aerospace Corporation, NorthWest Research Associates.
    1. Principal investigator at VT.
    2. Science operations center at VT, mission operations center at Illinois.

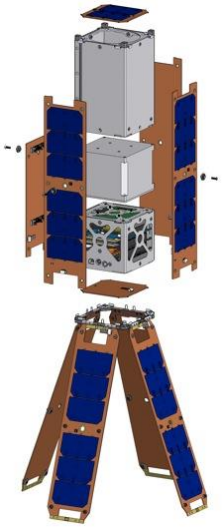
Current Status:

1. First 6U system funded through the NSF CubeSat program.
2. Seed funding provided by VSGC prior to the NSF award.
3. Also selected for deployment from the ISS through NASA's ELaNa program – scheduled launch in April 2016.
4. Instruments now being designed, built and tested by students at VT.
5. 22 students at VT have already been involved in LAICE; *many of these have received VSGC support*.

Space @ Virginia Tech
Center for Space Science and Engineering Research

DUst Sounder and Temperature Imager Experiment - DUSTIE





3U Cubesat w/ 1 instrument on NASA Manifest

Orbit	>500 km km circular, i=30-100°
Data Rate	4 Gbits /day
ADACS	0.5° 3σ Control & Knowledge
Mass	3.15 kg
Power	4W Required, 15W Generation

Mission Overview:

1. Measure cosmic dust as tracer of global dynamics and climate change.
2. Demonstrate instrument suite and attitude determination & control system (ADCS) – many future applications re- Earth science.
3. Develop sophisticated ADCS algorithms for accurate solar pointing.
4. Uplink and downlink using ground-stations at VT and elsewhere.
5. Partners: HU, NRL, USU/SDL, GATS

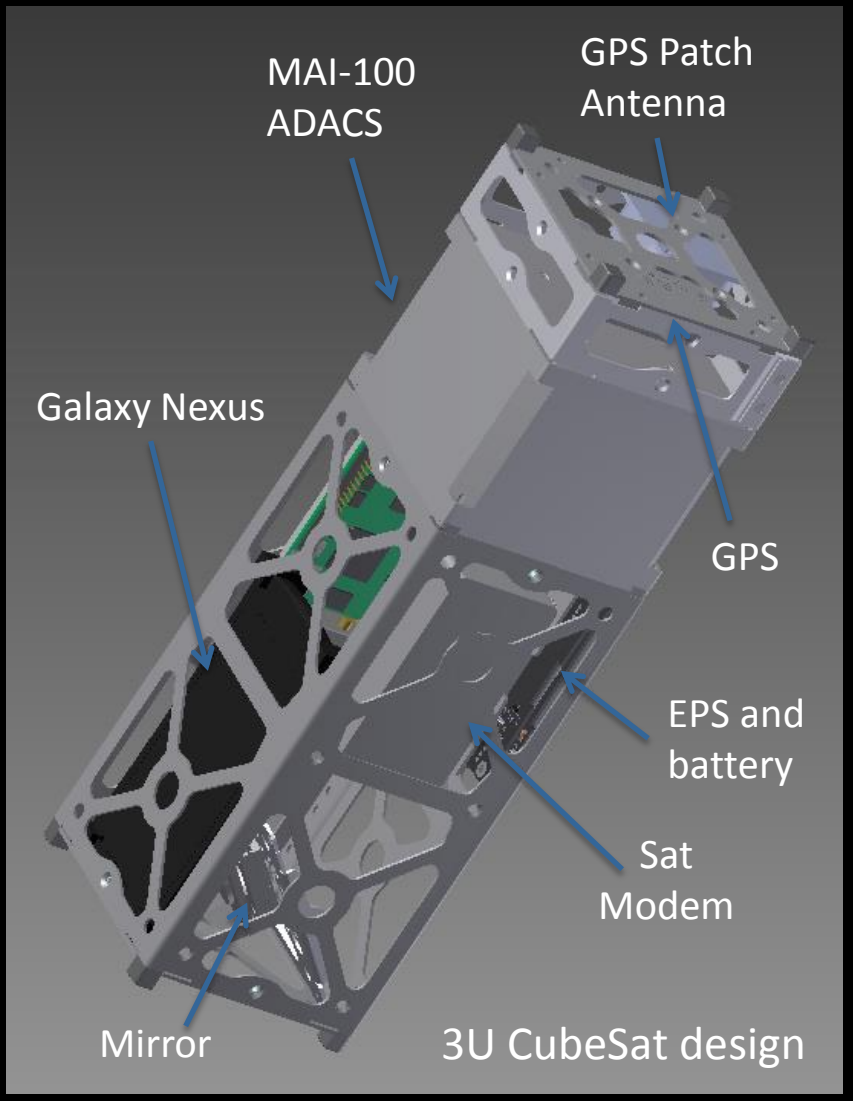
Current Status:

1. Selected for launch through NASA's ELaNa program, but no funding yet identified for payload and instrument development.
2. Optics designed, detector purchased and in-house.
3. S/C bus purchased from Pumpkin Inc.
4. Need communication system and development funds to finalize instruments and software.

VSGC Seed Funding Supported UVA JefferSat

- Can a smart phone be used for sensing and control on a satellite?
- Student design, build and fly small sat
- NASA funding for high altitude balloon flight

Samsung Galaxy Nexus



JEFFERSAT

ODU Ground Station

EQUIPMENT

- EA4TX ARS-USB Rotator Controller Interface used for controlling the antenna using the computer
- Yaesu G-5500 Rotator
- ICOM IC-910H Transceiver
- M2 Antenna Systems 436CP30 UHF Yagi Cross-Polarized Antenna
- M2 Antenna Systems 2MCP14 VHF Yagi Cross-Polarized Antenna

CAPABILITIES

Modes: AM, Wideband FM, FM-Narrow Band, CW

Receive Range: 136 – 174 MHz, 430 – 450 MHz

Transmit: 144 – 148 MHz, 430 – 450 MHz

Transmit Power: VHF 100 Watts, UHF 75 Watts

CURRENT OPERATIONS

Currently trying to record images from weather satellites

Plan to receive a transmission from the RockSat-C launch in 2015

Plan to serve as a ground station for LAICE satellite (Virginia Tech Project)

Plan to serve as a ground station for VSGC French cubesat project

Virginia Tech Ground-Station Capabilities

All systems will be based on software defined radio (SDR) technology, and will utilize the GNU Radio SDR Framework.

VHF / UHF System (Amateur Satellite Service):

- Antennas: Double Stack, Crossed Yagis (one pair per band)
- Polarization: RHCP/LHCP (selectable)
- Frequency: 144 – 148 MHz, 420 – 450 MHz
- Power Amplifiers: 160 W on VHF, 100 W on UHF

L/S Band System (Amateur Satellite Service):

- Antennas: 3.0m dish w/ Stepped Septum Feed (S-Band), crossed loop Yagis (L-Band).
- Polarization: RHCP/LHCP (selectable)
- Frequency: 2400 – 2404 MHz (RX-only), 1260 – 1270 MHz (TX-only)
- Power Amplifiers: 120 W on L-Band

4.5 meter Dish System (Radio Astronomy / EME):

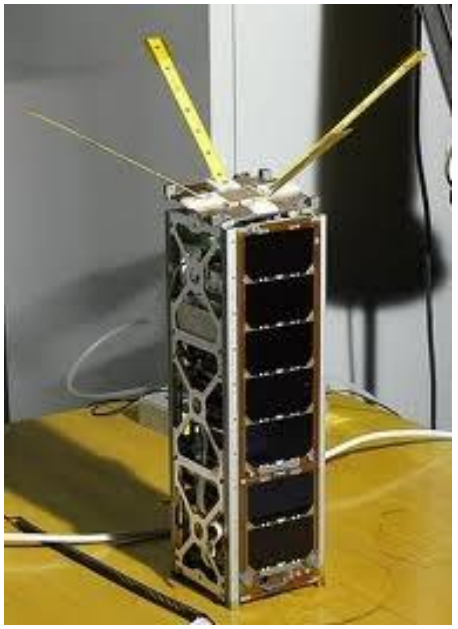
- Antennas: Multiple feed types depending on application
- Polarization: Multiple depending on application
- Frequency: 1296 MHz, 2304 MHz, 10.368 GHz (EME); 1420 MHz (RA)
- Power Amplifier: 120 W (1296), 150 W (2304), 15 W (10.368GHz)
- Backup for 3.0m S-Band System

Weather Satellite Systems (RX Only):

- Antennas: Loop Yagi for GOES satellites, Crossed Yagi for NOAA satellites
- Frequency: 1691 MHZ (GOES), 137 MHz (NOAA APT)

Small Satellite Working Group

- **VSGC established a Small Satellite Working Group in 2011 for networking, to plan for anticipated calls for proposals for small satellite initiatives, and to seek collaborative activities.**
- **Members currently include Virginia Tech, UVA, Old Dominion University, William and Mary, Hampton University, NASA Langley and NASA Wallops.**
- **Highly collaborative group.**
  - **Sharing of information and resources**
  - **Awareness of flight and funding opportunities**
  - **Ongoing communication and quarterly meetings**
  - **Working together on VSGC French cubesat initiative**
  - **Planning for participation in Space Grant Solar Eclipse 2017 project**



Classes of Small Sats

- minisatellites, 100-500 kilograms (220-1100 pounds);
- microsatellites are satellites between 10 and 100 kilograms (22-220 pounds).
- nanosatellites, 1-10 kilograms (2.2-22 pounds) (cubesats fit here);
- picosatellites, 0.1-1 kilogram (0.22-2.2 pounds);
- femtosatellites, less than 100 grams (0.22 pounds).

Small Sats Are Changing Space Business

Strong NASA, DOD and Security Agencies Interest in Small Sats

Strong commercial interest in Small Sats.

- Shortened development times
- Months to a few years from concept to orbit
- Low cost access to space
- Cheaper launch costs – can often serve as ballast for rockets (shared launch costs benefit launch provide as well)
- More timely technology development and scientific gains (don’t lose technology improvements lost in long design and development cycles for large spacecraft; can capitalize on latest scientific understandings)

Small Sats Are Changing Space Business

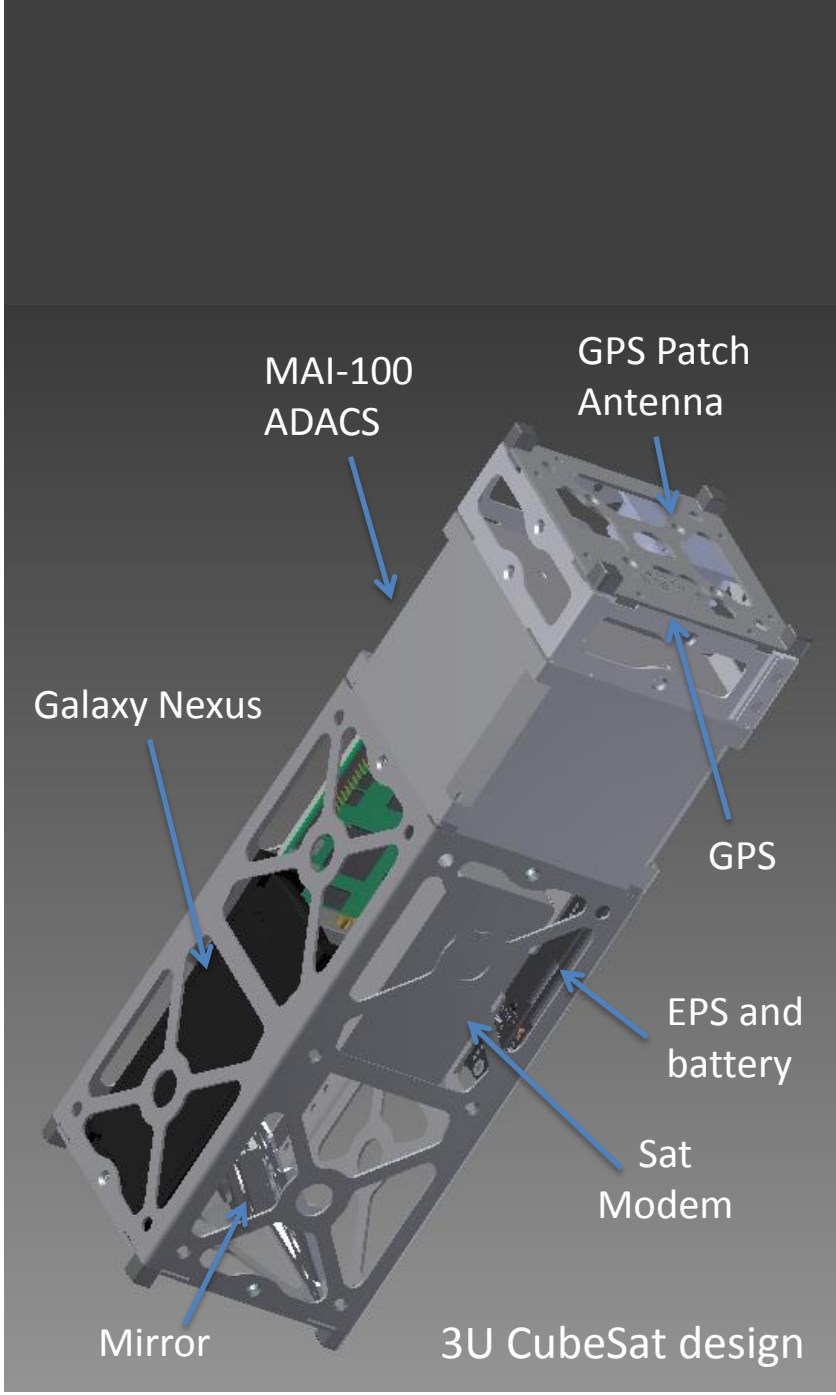
- Commercial off the shelf components allow plug and play
- Allows for higher risk tolerance
- Small Sats can be used for missions that larger satellites can’t perform, such as setting up a constellation of communication nodes or conducting in-orbit inspection of larger satellites.
- Permits smaller distributed platforms/constellations with more expansive coverage (Like QB-50)

Small Sat Technologies

"You can now, with a single chip, create most of the capabilities that you would have found in *Sputnik*, but, of course, orders of magnitude faster," says Mason Peck, a former chief technologist at NASA and now a professor at Cornell University. (Technology Quarterly, June 2014)

Smartphones and other consumer electronics provide a wealth of ready-made technologies. (UVa JefferSat)

A typical phone contains an accelerometer to measure how fast it is moving, a magnetometer to detect magnetic fields and provide a compass reading, a GPS receiver to pick up satellite data, multiple radios, a gyroscope to measure its position, a barometer to detect pressure, two cameras and much more.



Launch Opportunities Are Growing

Key Small Sat Virginia goal -- Capitalize on Virginia launch capabilities through MARS and NASA Wallops and to work with Virginia companies such as OrbitalATK and Intelsat General for launch services as appropriate.

Interorbital Systems, a Californian company, recently carried out a successful suborbital test flight of a small rocket (pictured right) designed to carry a 145kg payload. The company has presold berths for dozens of CubeSats at $13,000-38,000 per unit, as well as its own TubeSat format, which it offers to academia as kit and launch for $8,000.

Launch Opportunities Are Growing

- NASA launch opportunities for university payloads through Elana program as well as support for student payload development through the Undergraduate Student Instrument Program. NSF also has a small sat support program for universities.

- NASA will test an air-launched system in 2016 with Generation Orbit, an Atlanta company. It uses a Gulfstream G-IV executive jet to carry aloft a rocket which it fires off to put 45-50kg payloads into low-Earth orbit.

- NASA is also working with Virgin Galactic, a private space venture led by Richard Branson. Virgin Galactic has developed its LauncherOne, another air-launched rocket. It can be flown to a higher altitude and carry payloads up to 225kg.

- Other commercial and DOD ridesharing.

2014

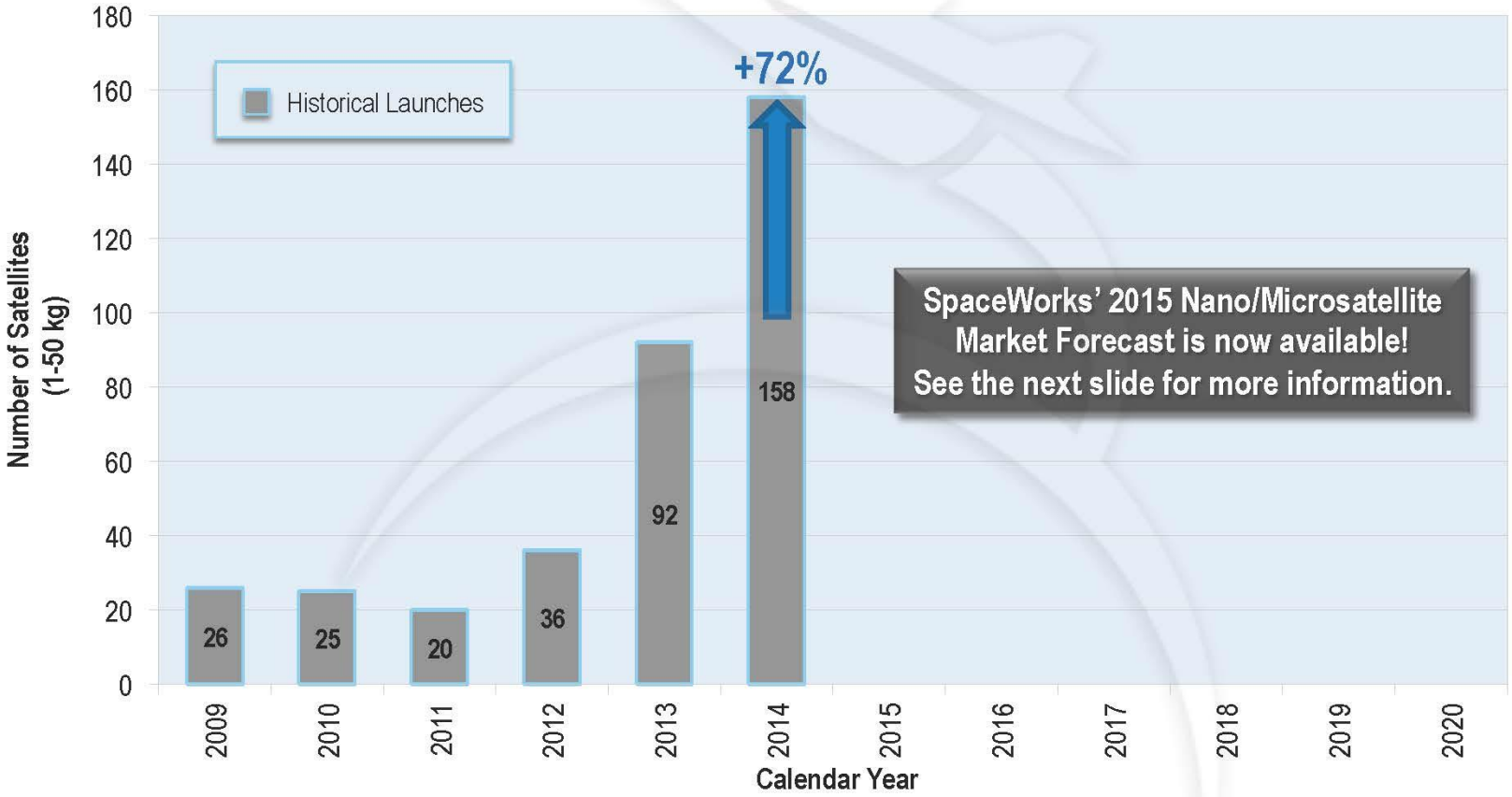
SpaceWorks' 2014 Projection estimated between 140 and 143 nano/microsatellites across all sectors would launch globally in 2014; 158 nano/microsatellites were actually launched. This represented an increase of nearly 72% compared to 2013.

2015+

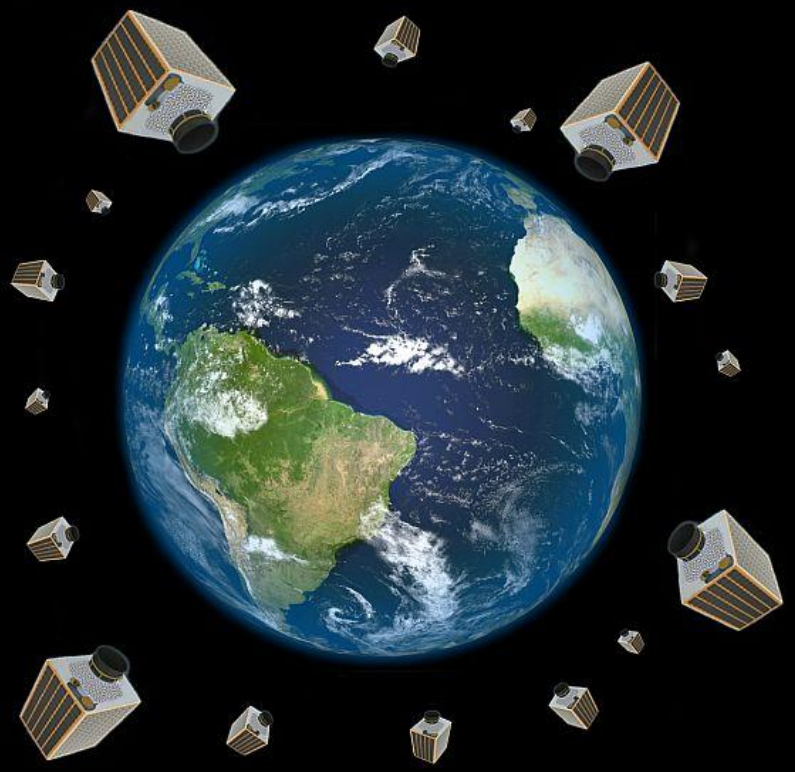
In 2014, 107 commercial nano/microsatellites (1-50 kg) launched and thousands of commercial small satellites (101-500 kg) are planned for launch over the next fifteen years. Recent multi-million and multi-billion dollar investments in various ventures confirm the commercial sector's continued interest in the nano/microsatellite and small satellite industries.

Nano/Microsatellite Launch History (1 – 50 kg)

The nano/microsatellite industry continues to thrive, with 158 satellites launched last year



Historical data includes failed launch attempts.
Historical data may not represent all global nano/microsatellite activities.
The number of satellites may not equal the number of launches since many small satellites are multiple-manifested (i.e. more than one satellite co-manifested on a particular launch vehicle).



Small Sat Projections

DARPA, the Pentagon's R&D arm, has been working on a number of Small Sat technologies designed to reduce their weight and improve reliability and performance.

Small satellites are moving from being experimental kits to delivering useful scientific data and commercial services.

In the next five years or so some 1,000 nanosats, as small satellites of 1-10kg are called, are expected to be launched. (Technology Quarterly, June 2014)

Cost Estimates for Small Sat Projects

(Technology Quarterly, June 2014)

Including the launch, a nanosat of CubeSat dimensions might cost $150,000 - $1m, rather than $200m -1 billion for a full-sized satellite.

Although there is no standard price list for a launch, a CubeSat costs roughly $100,000 to put each 1.3kg unit into low-Earth orbit. A three-unit CubeSat might cost as much as $400,000. Charges as low as $30,000 for a single CubeSat launched on a Russian rocket.

These prices put nanosats in the reach not just of small firms, but also of start-ups and researchers relying on academic grants.

Elon Musk of SpaceX has consistently predicted substantial price drops in launch costs, even to as little as $200 per kilo. The firm's Falcon 9 rocket recently demonstrated a successful controlled descent of its booster stage, which would allow it to be reused.

Recent Milestones

- November 19th, 2013 Orbital Sciences, a Virginia company, launched a rocket from the Wallops Flight Facility in Virginia. It carried 29 satellites aloft and released them into low-Earth orbit, a record for a single mission.
- Thirty hours later, Kosmotras, a Russian joint-venture, carried 32 satellites into a similar orbit.
- January 2014, Orbital Sciences carried 33 satellites up to the International Space Station (ISS), where they were cast off a month later.

The Virginia Joint Commission

JCOTS

on Technology and Science

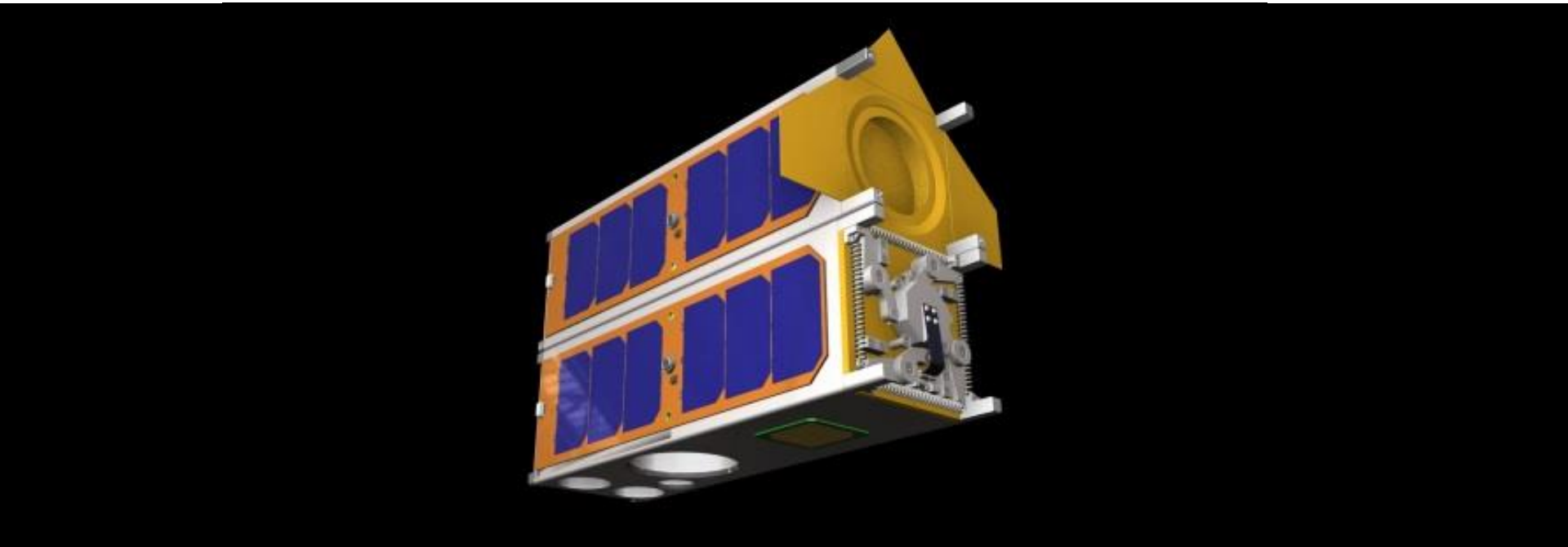
Nanosatellites Advisory Committee

Looking at next steps for the Commonwealth with respect to Nanosatellites

General charge -- to study the establishment of a Consortium of Space Science Education that would consist of universities, companies and other organizations in the field. The Consortium would advance research and development related to nanosatellite and cube satellites. Will look for possible federal partnerships, identify any impediments to the creation of a consortium and look at other incentives that might foster the creation and sustainability of a consortium.

Small Sat Virginia Initiative

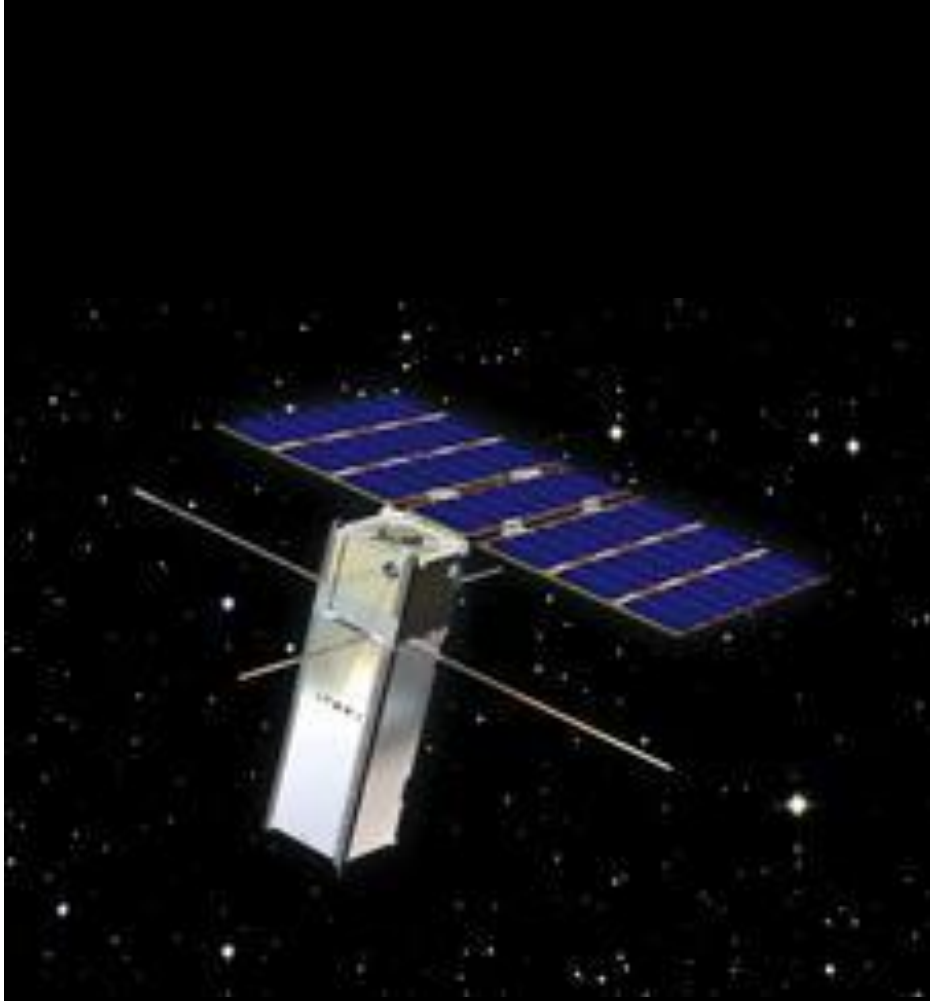
VSGC-led with NASA, university, industry and other collaborators.



Goal

Maximize Virginia engagement in Small Sat initiatives for

- ✓ economic development
- ✓ technology development and demonstration
- ✓ scientific advancement
- ✓ workforce development / STEM education
- ✓ enhanced utilization of state aerospace resources and capabilities.



Objectives

- Foster the development of university small sat initiatives at individual institutions and across institutions.
- Support instrument development and science objectives best achieved with small sat payloads.
- Engage university, industry and NASA partners.
- In partnership with the Mid-Atlantic Regional Spaceport and NASA Wallops seek opportunities for university as well as industry-led small sat launch opportunities and capabilities.

Objectives

- Pursue university-led and other small sat launches with NASA, NSF, DOD, private industry and other organizations as appropriate.
- Provide mentoring, professional development and cross training for faculty and students at Virginia universities, colleges and community colleges who wish to undertake small sat programs.
- Foster interest in flight projects at precollege institutions to contribute to STEM workforce pipelining.

Virginia's Aerospace Assets for Small Sats

- NASA Langley -- design, development, and environmental test and qualification expertise for cubesat payloads and cubesat and small sat flight systems, as well as participation in other NASA Launch Opportunities.
- NASA Wallops -- engineering and mission planning support services as well as participation in other NASA Launch opportunities.
- Mid-Atlantic Regional Spaceport (MARS) potential for launch services.

Virginia's Aerospace Assets for Small Sats

- Space@VT -- end-to-end expertise and facilities to design, build, test, and fly cubesats, other Small Satellites, and space payloads.
- UVa -- Research and education in space science and technology, including undergraduate flight projects.
- ODU -- expertise in both mechanical and electrical engineering aspects of small satellite systems, as well as systems integration. Specific strength areas include orbital mechanics (navigation, formation flying, orbital rendezvous), thermal physics and hypersonic flow for entry/descent, communications systems and electronic
- Ground Tracking Stations at Virginia Tech and Old Dominion University and potentially at Hampton University (in development).
- Virginia is fortunate to have companies such as Orbital ATK and IntelSat General with Small Sat capabilities including launch, payload and mission support services, as well as STC, which publishes an international, peer reviewed, Small Sat Journal. Many others still to be contacted!

Virginia's Aerospace Industry

Aerospace firms - 267 with 438 locations

Direct economic output of Virginia's Aerospace Industry of 7.4 billion plus $4.7 billion in support of additional economic activity in Virginia.

OrbitalATK, Intelsat General and STC in proposal, but *many* Virginia companies are expected to have an interest.

AEROSPACE IN VIRGINIA

Virginia
YesVirginia.org
BEST STATE FOR BUSINESS

Major Employers

AERIAL Machine & Tool
Aerojet
Alcoa Howmet
Aurora Flight Science
BAE Systems
Boeing
Cobham North America
Dynamic Aviation Group
EADS North America
Euro Composites
General Dynamics
Goodyear Tire & Rubber
Kollmorgen
L-3 Communications
Lockheed Martin
Measurement Specialties
Moog
Northrop Grumman
Orbital ATK
Raytheon
Rockwell Collins
Rolls-Royce N. A.
RTI International Metals
The Aerospace Corp.
Triumph Aerospace

Military and Federal

The Pentagon
Central Intelligence Agency
Dept. of Homeland Security
Fort Belvoir
Fort Lee
Fort Myer
Fort Pickett
Joint Base Langley-Eustis
Marine Corps Base Quantico
Missile Defense Agency
National Ground Intelligence Center
National Reconnaissance Office
Naval Air Station Oceana
Naval Surface Warfare Center, Dahlgren
Navy Commander Operational Test and Evaluation Force
Norfolk Naval Base
Office of Naval Research
Space and Naval Warfare Systems Command

Research and Development

Commonwealth Center for Advanced Manufacturing
Commonwealth Center for Aerospace Propulsion Systems
Defense Advanced Research Projects Agency
NASA Langley Research Center
National Center for Coatings Application, Research & Education
National Center for Hypersonic Combined Cycle Propulsion
National Institute of Aerospace
Virginia Modeling, Analysis, and Simulation Center
Virginia Space Grant Consortium

Education

University

Virginia Tech
University of Virginia
Old Dominion University
Virginia Commonwealth University
Liberty University
Hampton University
Averitt University

Community College

Blue Ridge Community College
John Tyler Community College
Thomas Nelson Community College

High School

Aviation Academy of Newport News Public Schools

Airports

Washington Dulles International Airport
Ronald Reagan Washington National Airport
Charlottesville-Albemarle County Airport
Lynchburg Regional Airport
Newport News-Williamsburg International Airport
Norfolk International Airport
Richmond International Airport
Roanoke Regional Airport
Shenandoah Valley Regional Airport
57 general aviation airports

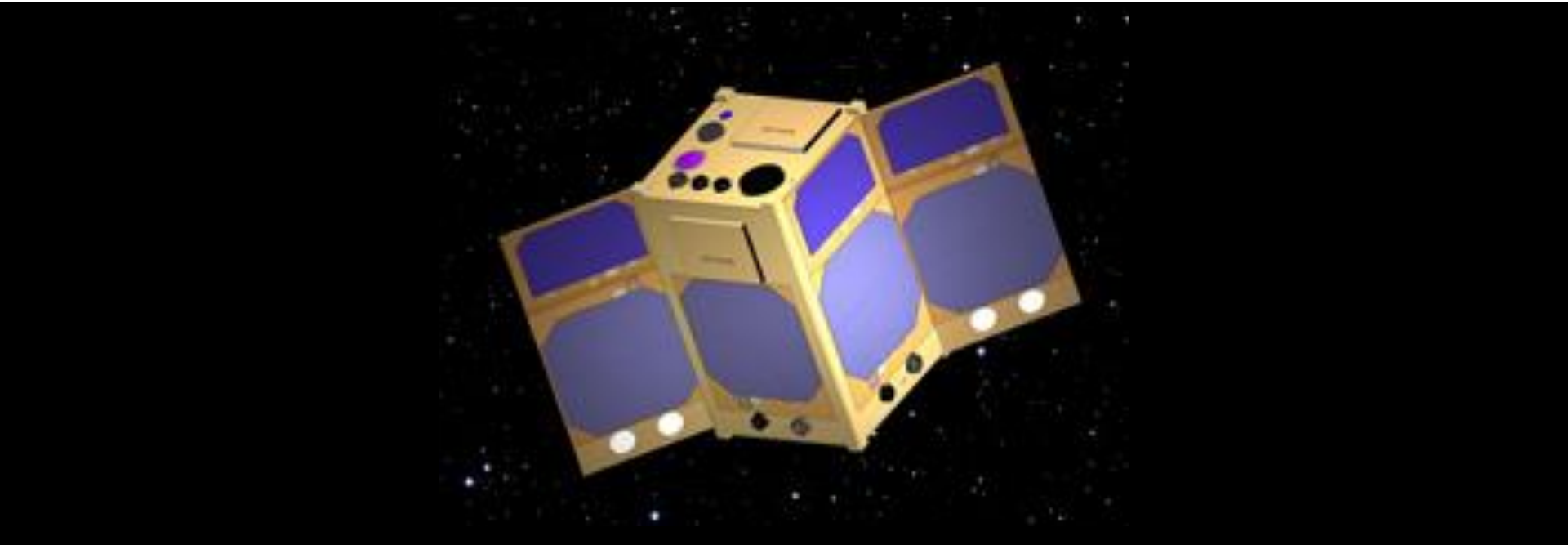
Workforce Development

- Workforce development is a key product for Small Sat Virginia.
- University Small Sat programs provide students with invaluable experience in real space missions providing a workforce pipeline to aerospace companies.
- Students learn the parameters and challenges of the space environment.
- Small Sat projects contribute to research infrastructure at Virginia institutions of higher education.

Organizational Structure

Lead: Virginia Space Grant Consortium

Advisory Committee -- VSGC Director and Program Manager, folks from Universities with active cubesat projects plus MARS, NASA Langley, NASA Wallops, Industry representatives and representatives from Technology, Transportation, Education and Commerce Secretariats.



Organizational Structure

Participants:

- ***Universities: UVA, Virginia Tech, Old Dominion University, William and Mary, Hampton University plus other Virginia Universities with Small Sat Interests***
- ***Other Organizations: Mid-Atlantic Regional Space Port (MARS), NASA Langley Research Center and NASA Wallops Flight Facility, National Institute of Aerospace***
- ***Companies: OrbitalATK (small sat services, potential launch opportunities with MARS TBD), IntelSat General (potential ride sharing, launch and early operations support); STC (Publish International Peer-Reviewed SmallSat journal). Others to be added.***
- ***Collaborators: Could include non-Virginia-based organizations that can support Virginia's Small Sat interests such as Kentucky Space, Student Spaceflight Experiments Program (Jeff Goldstein). LaRC Small Sat Mid-Atlantic Community Working Group.***

Budget estimate $4 million dollars per year.

Core/base funding from Commonwealth.

Leverage state funding through partnerships with federal, industry and other organizations.

Funding for Launch Opportunities – $1.5 million

- *Potential for MARS-led or Wallops launch opportunities*
- *Deployer development*
- *Funding pool to support other launch venues.*

$2 million - Small Sat payload and hardware projects plus any funding the Initiative is able to leverage from other sources. VSGC

Program Administration - $500K: Full time staff lead at VSGC plus half time administrative support, travel and other administrative costs - $200K; ODURF IDC of about $300K.